CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Interferometric Synthetic Aperture Radar Techniques (01402.158)

DATE/PLACE: August 5–9, 2002, Miami, Florida

AUTHOR: D. Marius Necsoiu

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BACKGROUND AND PURPOSE OF TRIP:

To take advantage of Professional Development Program offered by the CNWRA, I spent one week at the University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS), with Dr. Tim Dixon's group, learning about Interferometric Synthetic Aperture Radar (InSAR) techniques. These techniques uses radar signals to measure deformation of the Earth's crust over large areas in centimeter to millimeter measurement resolution. The types of crustal deformation include subsidence or uplift resulting from earthquakes, mining, dissolution of bedrock, pending vulcanic eruptions and groundwater withdrawal.

Land subsidence and soil compaction caused by overdraft aquifer systems is a worldwide problem affecting both agricultural and urban areas that depend heavily on ground-water supplies [*Poland*, 1984]. In the United States, more than 17,000 square miles in 45 States have been directly affected by subsidence. Many of the earth's urban and suburban areas are subsiding due to excess withdrawal of fluids, principally water but also oil, natural gas, and geothermal fluids [e.g. *Poland*, 1984]. While most subsidence rates, averaged over several years, are relatively small (<10 mm/yr) and spatially limited (<10 km), significantly higher subsidence rates are known (>3cm/year) and may extend over larger regions (>10 sq. km). These larger regions with significant subsidence increases the risk of flooding, infrastructure damage from differential subsidence of ground supports, and permanent degradation of natural reservoirs because of over pumping. Monitoring the spatial and temporal patterns of surface deformation associated with groundwater withdrawal allows quantification of net fluid flux (withdrawal versus recharge), provides insight into reservoir physical properties, and enables better risk assessment of potential damage to underground water reservoirs.

Traditionally, land subsidence is determined from precision leveling surveys. Leveling methods are adequate for monitoring land subsidence in selected locations with high precision but is time consuming and expensive for large areas. In contrast, differential SAR interferometry has the potential to provide important subsidence information because its large two-dimensional spatial coverage (tens of sq. km), it's accuracy (cm to mm), availability, and its competitive costs. For example, recent analysis of Mexico City's subsidence from ground water withdrawal using a combination of Interferometric Synthetic Aperture Radar (InSAR) for high spatial resolution and Global Positioning System (GPS) data for improved temporal information greatly improved ground subsidence monitoring in that city [*Cabral-Cano et al, 2002*].

SUMMARY OF PERTINENT POINTS:

The first two days of work were concentrated on learning about concepts and theoretical aspects of the InSAR techniques and software. The rest of the week work was dedicated to actual creation of the interferograms and phase referencing to an earth surface model.

The principle of the InSAR technique is as follows. Each pixel of a radar image contains information on the phase of the signal backscattered from the underlying surface. By utilizing the geometry provided by two marginally displaced, coherent observations of the surface, phase difference between the two observations can be related to surface height. To determine changes in elevation, a pair of SAR images are collected at different times from the same location, within a couple hundred meters. The second image is registered to the first image with an accuracy of greater than 1/8 pixel. This co-registration step is performed in the frequency domain using an automated Fast Fourier Transformation algorithm. By comparing the phase information from a pair of registered images, a set of fringes of interference is obtained. The resulting fringes are in the form of a series of rainbow-like bands outlining the differences in elevation or movement. One complete cycle of color bands represents a shift of half a wavelength.

The study area was Edwards Aquifer Recharge Area and we were interested in identifying small land subsidence due to water withdrawal. We analyzed six SAR images covering the San Antonio/Hondo/Uvalde area. Based on their coherence (coherence is a measure of the quality of the interferometric phases), pairs of datasets were created.

In processing InSAR data RSMAS uses two modules components of the Vexcel 3dSAR software: FOCUS and PHASE.

FOCUS contain the following subsystems: SAR parameter estimation, the range Doppler algorithm and the CEOS converter. This package is used to process ERS1/2, JERS and RADARSAT CEOS L0 (raw data) to CEOS L1 data. If ERS1/2 data is used the output products are CEOS SLC (Single Look Complex Image) and CEOS PRI (Precision Image).

PHASE is a complete synthetic aperture radar interferometry processing system. Input data required by PHASE consisted of two CEOS SLC images created by the FOCUS SAR Processing System, ground control points (GCPs) which are known map coordinates and a digital elevation model (DEM).

With PHASE, creating a displacement map involves 10 steps:
1. Resample the secondary SLC
2. Create the interferogram
3. Ingest DEM data
4. Simulate the phase due to topography from DEM
5. Register the simulated phase and interferogram
6. Substract the phase due to topography to create the flattened interferogram
7. Filter the flattened interferogram

8. Unwrap the flattened interferogram
9. Refine the geometry with GCP's
10. Create the displacement map and orthorectified SAR image

The best displacement map obtained was for the Uvalde/Sabinal Area (Figure 1).

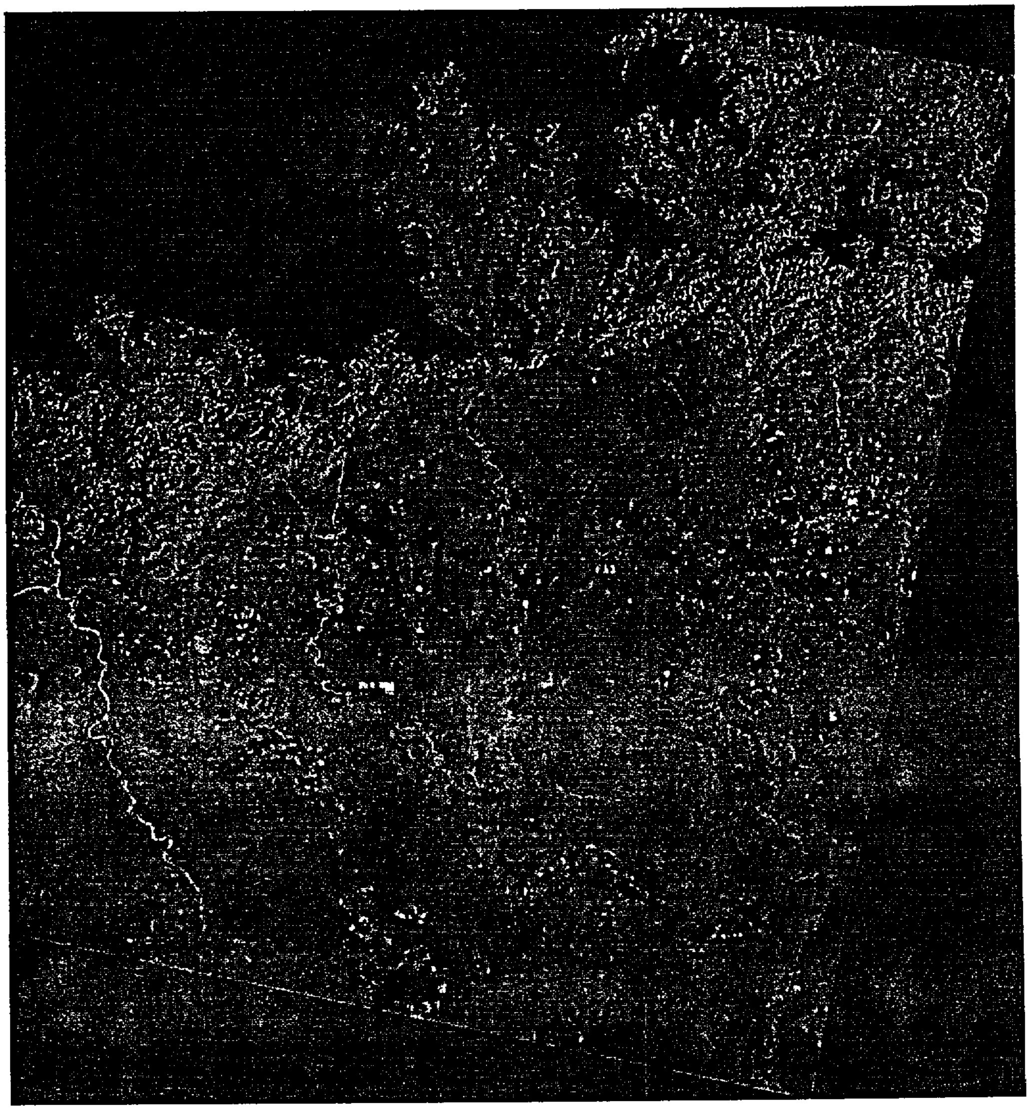

Figure 1. The interferometric phase laid over the power image for Uvalde/Sabinal pair

Interesting northeast-southwest trending linear features and point circular features were identified on this interferogram, near Uvalde (right side of the image). Future work is required including additional field work to identify the causes of those features and weather they are related to water subsidence.

CONCLUSIONS:

I greatly appreciate the opportunities of professional development that allows CNWRA researchers to widen their scientific horizons for the benefit of the Center.

InSAR techniques could be useful in studying earthquake displacement, volcano deformation, groundwater withdrawal, and even glacier dynamics or mass wasting phenomenon.

PROBLEMS ENCOUNTERED:

Due to the problems in the 30x30 m USGS DEM data we could not succesfully remove the phase effect on the San Antonio pair of radar images. The problem could be eliminated if a better DEM is available and used in the interferometric procedure.

PENDING ACTIONS:

If time and money are available, a GIS will be created for the areas covered by radar data in order to refine and completely understand this technique. The GIS will include coherence and displacement maps as well as wells, roads and railroads location.

Based on a newly created DEM, the same procedure will be repeated at RSMAS. The results will be compared with the existing ones.

REFERENCES:

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